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BULLETIN

OF THE

AMERICAN PHYSICAL SOCIETY

PROGRAMME OF THE

PITTSBURGH MEETING

AT

PITTSBURGH, PENNSYLVANIA

March 8–10, 1951

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OF THE

AMERICAN PHYSICAL SOCIETY

PITTSBURGH MEETING, MARCH 8–10, 1951

THE **three hundred and fourth meeting of the American Physical Society will be held in Pittsburgh, Pennsylvania,** in the Mellon Institute for Industrial Research, the University of Pittsburgh, and the Bureau of Mines, on Thursday, Friday and Saturday, **March 8, 9, and 10, 1951.** The meeting will be administered by a Local Committee headed by J. E. Goldman. Solid-state physics and chemical physics will be particularly well represented in this meeting: this we owe largely to our new Division of Chemical Physics and to our long-established Division of Solid-State Physics.

There seems to be some misunderstanding about the distinction between general meetings and Divisional meetings. This is a general meeting of the American Physical Society. It comprises the Annual Business Meetings of the two Divisions aforenamed, and in this sense may be said to include their Annual Meetings. It comprises also an extraordinary number of invited papers solicited by these Divisions and grouped into "Symposia." Fired with enthusiasm not adequately tempered by experience, the authorities of the Divisions arranged a joint symposium for Thursday morning, and in addition *four* half-day sessions of invited papers in the field of solid-state physics and *five* half-day sessions of invited papers in the field of chemical physics. Evidently the Division of Chemical Physics was assuming that there would be no ten-minute papers in its field, and the Division of Solid-State Physics was assuming that there would be few enough in its field to be accommodated on Saturday afternoon and in interstices between the symposia; neither was right. No responsibility is accepted by the Society for inconvenient simultaneities, nor for cases of nervous prostration arising from attempts to assimilate too much knowledge in three days.

The **registration desk** will be located in the Mellon Institute; this is a vast colonnaded building in Greco-Roman style, situated at the corner of Fifth Avenue and Bellefield Avenue; *enter on the Bellefield-Avenue side.* The Bureau of Mines is at 4800 Forbes Street, uptown from Mellon Institute; the high tower of the University of Pittsburgh, known as the Cathedral of Learning, is unmissable. This is the Oakland area of Pittsburgh, in which are also the University of Pittsburgh, the Syria Mosque (see below), and the Schenley and Webster Hall Hotels. People coming from the East should get off the train at East Liberty station unless they are going to the William Penn or some other downtown hotel, in which case they should continue to Union Station. From downtown, take any uptown-bound car on Fifth Avenue bearing a number in the seventies, and allow twenty minutes for the journey. Hotel reservations, if not already made, should be made at once with mention that the writer is a member of the Society. All members and guests are asked to register, and frequently to consult the bulletin board for notice of messages.

The **opening session** of the meeting will be the **joint Symposium of the Division of Chemical Physics and the Division of Solid-State Physics, to be held in the Mellon Institute Auditorium** beginning at 10:00 A.M. As this event is the inauguration of the new Division, it will commence with brief addresses by the Vice-President of the American Physical Society and the Chairmen of both Divisions.

The **remaining Symposia of the two Divisions** are listed hereinafter. The room assignments for these and the sessions of contributed papers are not decided as this Bulletin goes into page proofs, and if they are still undecided when the proofs are returned for printing, they will be announced on the bulletin board at Mellon Institute and will be omitted from the pages of this Bulletin.

Nuclear physics will feel rather lonesome at this meeting; the problem of attracting nuclear physicists *en masse* to our March meeting, and thus lessening the overcrowding at the New York and the Washington meetings, is one which the Society

has not yet succeeded in solving. Nevertheless we shall be able to offer a description of the **great new cyclotron of the Carnegie Institute,** to be given by E. C. Creutz on Saturday afternoon.

Sixty contributed papers are distributed among five sessions, making up a total which would have been very impressive only a few years ago, and is still quite satisfactory.

The **banquet of the Society** will be held on **Thursday** evening (*not* on Friday) in the Webster Hall Hotel; the price will be $3.50, including taxes and tips. Please make reservations in advance by using the form on the inside back cover page. Tickets will be sold at the registration desk, and the Society reserves the right to dispose of uncalled-for and unpaid-for tickets to the first comer after 3:00 P.M. on Thursday afternoon. The after-dinner programme, if not arranged by the time this Bulletin goes to press, will be announced on the bulletin board.

On **Friday evening** there is to be a **concert of the Pittsburgh Symphony Orchestra** in the Syria Mosque; by an unprecedented and welcome arrangement for which we have to thank the Chairman of the Local Committee, tickets at one-third reduction of price will be available to our members, and will be sold at the registration desk.

The **Council of the American Physical Society** will meet on Saturday afternoon at 3:00 P.M. in the Board Room of the Mellon Institute.

Post-deadline papers will be considered for acceptance into a special supplementary programme if the abstracts thereof reach the office of the Society not later than Friday, March 2. This privilege is extended by the Council only to a small number of papers concerning very recent achievements of very special importance. The abstracts will not be published. Such papers as are accepted will be assigned to the end of Session P, and will be announced on the bulletin board.

Prospective meetings of the Society are scheduled as follows: Washington, D. C., April 26–28; Schenectady, New York, June 14–16; Vancouver, British Columbia, June 25–28; Chicago, Illinois, October 25–27 (joint meeting with the American Institute of Physics and the other Founder Societies of that Institute); Houston, Texas, November 23–24.

General Rules Relating to Papers

The time allowed for the presentation of a contributed paper is ten minutes at most. With respect to those which appear in the "supplementary programme" the Chairman of the session indicated in a footnote to each paper is empowered to reduce its allotment of time to less than ten minutes or to read it by title. (These are the papers of which the authors have other papers on the regular programme.)

The abstracts of the papers contributed to the Pittsburgh meeting, which follow hereinafter, will be reprinted in *The Physical Review* exactly as they stand here. The procedure for submission of errata was described in the 1950 Washington Bulletin and in the 1950 Oak Ridge Bulletin; the errata must be received by Miss Ruth Bryans, 57 East 55 Street, New York 22, New York, not later than March twenty-third. The type cannot be altered to even the slightest extent without forfeiting the economies for the sake of which the new policy has been adopted. Under no circumstances send your original abstract to Miss Bryans with alterations marked upon it; write out the errata (examples, far too numerous, can be found in *The Physical Review*).

Speakers must retrieve their lantern slides before leaving the hall in which their papers were given. The Local Committee is under no obligation to keep or to return them.

Karl K. Darrow, *Secretary*
American Physical Society
Columbia University
New York 27, New York

EPITOME OF THE PITTSBURGH MEETING

(Personal names are those of invited speakers. DSSP stands for Division of Solid-State Physics: DCP for Division of Chemical Physics.)

Thursday Morning

A. Joint Symposium of DSSP and DCP on electronic states of molecules and solids: Van Vleck, von Hippel, Mulliken; Mulliken, Slater, Loewdin. Mellon Institute Auditorium.

Thursday Afternoon

B. Symposium (DSSP) on vibration and relaxation spectra of solids: Montroll, von Hippel, Herzfeld. Mellon Institute Auditorium.
C. Symposium (DCP) on molecular structure and valence theory: Roothaan, Parr, Pake. Business Meeting of DCP. Bureau of Mines.
D. Semi-conductors mostly. Mellon Institute Social Room.

Thursday Evening

Banquet of the American Physical Society. Webster Hall Hotel.

Friday Morning

E. Symposium (DSSP) on divers topics: Becker, Seitz, Shockley. Mellon Institute Auditorium.
F. Symposium (DCP) on molecular structure and valence theory, concluded: Rundle, Townes, Gordy, Herzberg. Bureau of Mines.
G. Optical, chemical, and general physics. Mellon Institute Social Room.

Friday Afternoon

H. Symposium (DSSP) on luminescence, photo-effect, electron and exciton migration: Schulman, Kallmann, Apker and Taft. Mellon Institute Auditorium.
I. Symposium (DCP) on barriers to internal rotation of molecules and related stereo-isomerism: Kimball, Aston, Bernstein, Beckett, Burkhardt. Bureau of Mines.
J. Metals. Mellon Institute Social Room.

Friday Evening

Concert of Pittsburgh Symphony Orchestra.

Saturday Morning

K. Symposium (DSSP) on ferromagnetism and antiferromagnetism: Casimir, Kittel, Maxwell, Shull. Mellon Institute Auditorium.
L. Symposium (DCP) on statistical-mechanical aspects of chemical physics: Hirschfelder, Mayer, Hirschfelder and Curtiss, Grad, Montroll, and Berlin. Bureau of Mines.
M. Nuclear physics. University of Pittsburgh, Room 324.

Saturday Afternoon

N. Symposium (DCP) on statistical-mechanical aspects of chemical physics, concluded: Buff, Eyring and Gibbs, Hicks, Mazur and Kirkwood. Mellon Institute Auditorium.
P. Creutz; magnetism; non-metallic crystals. University of Pittsburgh, Room 324.

PROGRAMME

THURSDAY MORNING AT 10:00

Mellon Institute Auditorium

(F. SEITZ presiding)

Inaugural Remarks. J. H. VAN VLECK, *Harvard University.*
Welcome to the new Division of Chemical Physics. A. VON HIPPEL, *M.I.T.*
Response by the Chairman of the Division of Chemical Physics. R. S. MULLIKEN, *University of Chicago.*

Joint Symposium (DSSP and DCP) on Electronic States of Molecules and Solids

A1. Some Aspects of the Electronic Structure Theory of Molecules. R. S. MULLIKEN, *University of Chicago.* (40 min.)
A2. Electronic Theory of Molecules and Crystals. J. C. SLATER, *M.I.T.* (40 min.)
A3. Overlap Integrals and Many-Orbital Effects in the Theory of Molecules and Crystals. P. O. LOEWDIN, *University of Uppsala.* (40 min.)

THURSDAY AFTERNOON AT 2:15

Mellon Institute Auditorium

(J. C. SLATER presiding)

Symposium (DSSP) on Vibration and Relaxation Spectra of Solids

B1. Vibrational Spectra of Solids. E. W. MONTROLL, *New York University.* (40 min.)
B2. Dielectric Relaxation Phenomena in Liquids and Solids. A. VON HIPPEL, *M.I.T.* (40 min.)
B3. Elastic Spectra of Liquids and Solids. K. HERZFELD, *Catholic University of America.* (40 min.)

THURSDAY AFTERNOON AT 2:15

Bureau of Mines

(J. O. HIRSCHFELDER presiding)

Beginning of the Symposium (DCP) on Molecular Structure and Valence Theory

C1. The Self-Consistent-Field Molecular-Orbital Theory. C. C. J. ROOTHAAN, *University of Chicago.* (40 min.)
C2. Theory of Normal and Excited States and Ultraviolet Spectra of Unsaturated Hydrocarbons. R. G. PARR, *Carnegie Institute of Technology.* (40 min.)
C3. Nuclear Magnetic Resonance in Studies of Molecular Structure and Internal Motions. G. E. PAKE, *Washington University.* (40 min.)

First Annual Business Meeting of the Division of Chemical Physics

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THURSDAY AFTERNOON AT 2:15

Mellon Institute Social Room

(J. BARDEEN presiding)

Semi-Conductors Mostly

D1. Germanium Films. J. W. THORNHILL AND K. LARK-HOROVITZ, *Purdue University.*—Deposition of germanium films in a high vacuum onto quartz and glass was studied as a function of rate of evaporation and temperature of substrate. The thickness (0.5μ–7μ) of these films was measured interferometrically. (K. W. Meissner) x-ray diffraction indicated

the normal diamond lattice without any preferential orientation and particle size of 100–400A, depending on the temperature of the substrate. Measurements of resistivity and Hall effect show that all films, regardless of the starting material used, are P-type with apparent room temperature mobilities between 1–50 cm²/sec volt indicating resistivity contributions due to scattering by defects, grain boundaries, and possibly trapping. High frequency measurements between 2 kilocycles and 2 megocycles show no variations of film resistance or capacity (Odell).

D2. Capacity Effects in $P-N$ Boundaries in Germanium.* N. H. ODELL AND H. Y. FAN, *Purdue University.*—The capacity of a $P-N$ junction produced by deuteron bombardment[1] has been measured as a function of temperature and of frequency. The frequency range was 50 kilocycles per second to 4 megacycles per second. The temperature range was room temperature to −155°C. A signal voltage, small compared with kT/e, was applied across the barrier in all cases. The barrier capacity exhibited a decided dependence on temperature, decreasing by several orders of magnitude from room temperature to −55°C at the lower frequencies and by a factor of approximately 3 for the same temperature range at the higher frequencies. Between −55°C and −155°C, the decrease was approximately by a factor of 2. At room temperature, the capacity of the sample exhibits a frequency dependence of approximately $1/f$, whereas at the two lower temperatures, the dependence is small. These results are consistent with the hypothesis that at room temperature part of the current is carried by holes in the N region at the barrier and by electrons in the P region.

* Work assisted by Signal Corps contract.
[1] Davis, Johnson, Lark-Horovitz, and Siegel, Phys. Rev. **74**, 1255 (1948).

D3. Electron Bombardment of Ge. E. E. KLONTZ AND K. LARK-HOROVITZ, *Purdue University.**—Theory (M. M. Mills)[1] predicts lattice displacements produced in Ge by electrons of energies greater than 0.56 Mev. By using electron currents of 1–5 microamps (energies between 0.7 and 2.0 Mev.) from a Van de Graaff generator,[2] the following displacements were observed: N-type Ge is converted to P-type, thus allowing detection of the effect by observing the rectification characteristic. A threshold for the effect was found between 0.5 and 0.7 Mev. As is observed in heavy particle irradiation,[3] the resistance of an N-type sample increases on bombardment, reaches a maximum, and then on conversion decreases again. The resistance of a P-type sample decreases. From the conductivity vs irradiation curve on one N-type sample, it was found that about one defect occurs for 10 incident electrons. After irradiation, a decrease in the resistance of N-type samples indicates healing. In some cases, barriers produced by irradiation are highly photosensitive at low temperature.

* Partially supported by the U. S. Signal Corps and the AEC.
[1] Personal Communication.
[2] We are indebted to the Van de Graaff group at the University of Notre Dame and to the Argonne National Laboratories in Chicago for the irradiations.
[3] Lark-Horovitz, Bleuler, Davis, and Tendam, Phys. Rev. **73**, 1256 (1948).

D4. Conversion of a Classical Semiconductor in Thermal Equilibrium from N- to P-Type.* V. A. JOHNSON AND K. LARK-HOROVITZ, *Purdue University.*—The behavior of germanium under the effects of bombardment-induced transmutations is similar to that of lead sulfide under the action of oxygen or sulfur. Irradiation converts N-type germanium into P-type. If lattice defects are healed out, the observed changes in electrical properties are due to transmutations.[1] These changes agree with theoretical predictions[2] assuming a classical semiconductor in thermal equilibrium. At constant temperature, the electron concentration times holes concentration is constant ($n_e n_h = K$). As acceptor impurities, n_A, are produced, electrons leave the conduction band until only intrinsic electrons remain; then holes are produced in the full band. Taking the mobility ratio as 1.5, one calculates that a germanium sample with an initial impurity electron concentration N shows, as bombardment progresses, increase in magnitude of the negative Hall coefficient R until $N-n_A=1.24K^{\frac{1}{2}}=2.4\times10^{13}$ cm^{-3} at 300°K. R then decreases in magnitude while the conductivity continuously decreases to a minimum when $n_A-N=0.41K^{\frac{1}{2}}=0.78\times10^{13}$ cm^{-3} at 300°K. The conductivity then increases, whereas R becomes zero when $n_A-N=0.83K^{\frac{1}{2}}=1.6\times10^{13}$ cm^{-3} at 300°K and passes through a positive maximum at $n_A-N=3.01K^{\frac{1}{2}}=5.7\times10^{13}$ cm^{-3} at 300°K.

* Assisted by Signal Corps Contract.
[1] Cleland, Lark-Horovitz, and Pigg, Phys. Rev. **78**, 814 (1950).
[2] V. A. Johnson and K. Lark-Horovitz, Report on Reading Semiconductor Conference (in press).

D5. The Effect of Fast Neutron Bombardment on the Conductivity of P-Type Ge. J. W. CLELAND, J. H. CRAWFORD, K. LARK-HOROVITZ, AND J. C. PIGG, *Oak Ridge National Laboratory.*—The number of positive carriers introduced per incident neutron into P-type Ge depends to some extent on the past history of the sample and the temperature of the exposure. The former factor exists since it has been shown that the P-type conductivity slope is dependent on the initial carrier concentration at low temperature and when the material is originally N-type and has been converted by bombardment. The latter factor is expected, since only those carriers which are thermally ionized are effective in increasing the conductivity. Data is presented concerning the dependence of rate of P-type conductivity change with bombardment on the initial properties of the material for different temperatures. The effect of temperature on carrier concentration and mean free path is also discussed.

D6. Pile Irradiation of Semiconducting Cu_2O. J. C. PIGG, J. W. CLELAND, J. H. CRAWFORD, AND K. LARK-HOROVITZ, *Oak Ridge National Laboratory.*—A number of Cu_2O polycrystalline plates[1] were exposed in the Oak Ridge nuclear reactor and the conductivity was measured during the bombardment. Several Cu_2O rectifiers, both commercial units and specially prepared disks,[1] were also exposed and the resistance, forward and back, was followed during the bombardment at a reference voltage. In addition, on several of the rectifiers, forward and back I–V characteristic curves were measured, periodically, throughout the bombardment. The conductivity of Cu_2O plates decreases, initially quite rapidly, with bombardment approaching a limiting value. Cu_2O rectifiers show large increases of forward resistance on bombardment with only a small increase in the reverse direction. After sufficient bombardment, the units approach ohmic behavior. The commercial units behave qualitatively the same as the specially prepared disks.

[1] We are greatly indebted to Dr. S. J. Angello of Westinghouse Research Laboratories for making available to us the Cu_2O plates and rectifying disks.

D7. Electron Bombardment Induced Conductivity in Germanium Point Contact Rectifiers. A. R. MOORE AND F. HERMAN, *RCA.*—Bombardment of semiconductors with Mev electrons results in transient changes in conductivity, as well as semi-permanent changes due to lattice defects. By operating with electron beams in the kev range, which is below the threshold for introduction of defects, we have studied the transient effects of bombarding electrons on germanium point contact rectifiers. The experimental method employs television-type scanning of the crystal by the electron beam in the neighborhood of the probe. The results are presented on a kinescope as a map of induced conductivity over the surface

of the germanium. The maximum diode current flows when the beam is within 2×10^{-3} cm of the probe. Recombination of electrons and holes reduces the current as the beam moves away from the probe. The ratio of change in diode current to beam current is unusually large; values up to 5×10^{4} have been measured for a 10 kev beam. Some of this current multiplication is attributed to a secondary effect at the barrier. By measuring the delay of the signal at different scanning lines, the mobility of holes in *N*-type germanium was obtained. The result was 1590 cm²/volt-sec, in agreement with other methods.

D8. On the Direct Current Voltage Characteristic of Metal-Semiconductor Contacts. K. LEHOVEC, *Signal Corps Engineering Laboratory.*—The influence of surface states on the current voltage characteristic of a metal-semiconductor contact is calculated under the following assumptions: (1) there is a continuous energy spectrum of surface states; (2) the occupation of the surface states with electrons is determined (a) by the electron distribution in the metal, if the carriers of current flow from metal to semiconductor (blocking direction), and (b) by the electron distribution in the bulk semiconductor, if the carriers flow from semiconductor to metal (forward direction). For sufficiently large voltages, E, the current increases as

$$I \approx I_F \cdot \exp(aE); \quad a \lesssim e/kT \quad \text{(forward direction)}$$

and

$$I \approx I_B \cdot \exp[b(e)^{\frac{1}{2}}] \qquad \text{(blocking direction)}.$$

Measurements on Ge-, Si-, and SiC-detectors, and on Cu_2O- and Se-rectifiers are compared with these results.

D9. Germanium-Indium Alloys as Low Temperature Resistance Thermometers.* SIMEON A. FRIEDBERG, *Carnegie Institute of Technology.*—A previous survey of semiconducting samples** indicates that materials with about 2×10^{17} impurity centers/cm³ and room temperature resistivities of about 0.05 ohm cm should have large enough temperature coefficients of resistivity at liquid helium temperatures to make good secondary thermometers. Experiments on *p*-type samples cut from a melt of germanium and 0.001 atomic percent indium are described. The influence of the original location of a sample in the melt on the magnitude and reproducibility of its change of resistivity with temperature is discussed. Satisfactory thermometers have been obtained from such a melt by surveying the resistivities between 4.2°K and 1.6°K of samples from slices taken perpendicular to the vertical axis. Strips from the uppermost layer of the melt are found to have about 1.5×10^{17} impurity centers/cm³ and resistivities at 300°K of about 0.08 ohm cm. From this group, a thermometer has been selected having a temperature coefficient of resistivity of -1 (deg. K)$^{-1}$ at 4°K and -370 (deg K)$^{-1}$ at 2°K. Its use in temperature measurement, reproducible to better than 0.01°K throughout the helium range, is discussed.

* This work has been assisted by the ONR and the Research Corporation.
** I. Estermann, Phys. Rev. **73**, 83 (1950).

D10. The Optical Properties of Donor and Acceptor Impurities in Silicon. E. BURSTEIN, J. J. OBERLY, J. W. DAVISSON, AND B. W. HENVIS, *Naval Research Laboratory.*—Data on the optical absorption of neutral donor and acceptor impurities have been obtained from low-temperature infrared transmission measurements for impurity concentrations ranging from 10^{16} to 10^{18} atoms per cm³. The impurities are found to exhibit absorption bands characteristic of the photoelectric absorption by *K* shell electrons. Data obtained near the ionization limit in *N*-type silicon containing 10^{16} donor atoms per cm³ ($E_I \sim 0.05$ ev) indicate an optical cross section of 3×10^{-15} cm² per impurity atom, which is in fairly good agreement with the theoretical value (1.7×10^{-15} cm²) for the hydrogen-like model.[1] The observed absorption at frequencies beyond the ionization limit ($h\nu \gtrsim 3E_I$) in *P*-type silicon containing 10^{18} acceptor atoms per cm³ is likewise in rough agreement with the theoretical values. These results are a further confirmation of the validity of hydrogen-like models for neutral donor and acceptor impurity atoms in homopolar semiconductors with high dielectric constants.

[1] H. Hall, Revs. Modern Phys. **8**, 358 (1936); H. Bethe, *Handbuch der Physik*, 2nd Edition XXIV/1, p. 477.

D11. Thermoelectric Power in Carbons and Graphite. EGON E. LOEBNER, *University of Buffalo* (*Introduced by* S. MROZOWSKI).—Raw cokes and baked carbon rods prepared by different processes were treated to different temperatures, and their thermoelectric powers were determined *versus* platinum at room temperature. All emf's found are negative; their absolute values show an interesting variation with temperature of treatment. Starting from cokes treated to 700°C, for which the resistivity is low enough to enable a measurement, the thermal emf decreases from a value of several tens of microvolts per °C to a minimum of approximately 8 microvolts/°C around 1400°C. A maximum of about 35 microvolts/°C occurs around 2200°C. This is followed by a sudden drop to about 10 microvolts/°C at 2550°C, and then a slow decrease with increasing graphitizing temperature toward a limiting value of a few microvolts/°C for Ceylon graphite. This general trend is in best agreement with the proposed examination of the electronic conductivity of graphite and carbons.[1] The treatment dependence in the lower region is caused by an increase of the number of excess electrons (removal of hydrogens) followed by a decrease due to crystallite growth. The drop above 2200°C occurs when the decreasing band separation becomes comparable to kT, thus allowing additional electrons to be activated.

[1] S. Mrozowski, Phys. Rev. **77**, 838 (1950).

THURSDAY EVENING AT 7:00

Webster Hall Hotel

(C. C. LAURITSEN or J. H. VAN VLECK presiding)

Banquet of the American Physical Society

FRIDAY MORNING AT 9:30

Mellon Institute Auditorium

(A. VON HIPPEL presiding)

Symposium (DSSP) on Divers Topics

E1. The Frequency Dependence of the Permeability of Ferromagnetics. R. BECKER, *University of Goettingen.* (40 min.)

E2. The Properties of Silver-Halide Crystals. F. SEITZ, *University of Illinois.* (40 min.)

E3. The Behavior of Holes and Electrons in Germanium. W. SHOCKLEY, *Bell Telephone Laboratories.* (40 min.)

Annual Business Meeting of the Division of Solid-State Physics

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FRIDAY MORNING AT 9:30

Bureau of Mines

(E. BRIGHT WILSON presiding)

Conclusion of the Symposium (DCP) on Molecular Structure and Valence Theory

F1. Bridge Bonds and Valence Theory. R. E. RUNDLE, *Iowa State College.* (30 min.)

F2. Evidence on Bond Characters from Nuclear Quadrupole Effects. C. H. TOWNES, *Columbia University.* (40 min.)

F3. Molecular Structures from Microwave Spectra. W. GORDY, *University of North Carolina.* (30 min.)

F4. Predissociation of the Nitrogen Molecule. G. HERZBERG, *National Research Council of Canada.* (20 min.)

FRIDAY MORNING AT 9:30

Mellon Institute Social Room

(DAVID HALLIDAY presiding)

Optical, Chemical, and General Physics

G1. Atmospheric Transmission of Solar Radiation in the 35 to 75 Micron Region.* GLENN L. MUSSER AND RICHARD C. RAYMOND, *Pennsylvania State College.*—Radiation from the sun in the 35 to 75 micron region has been isolated by means of differential filters. The radiation was focused by a sixty-inch parabolic mirror onto a thermocouple. The mirror surface was blackened, and a combination of quartz and deposited filters removed most of the short wave radiation. The 35 to 75 micron components reaching the thermocouple were identified by use of a sodium chloride plate, which removes these components of radiation. The system was calibrated by use of a black-body source placed approximately ten meters from the receiver. Solar signals could be obtained only when the sky was perfectly clear. The total power in the 35- to 75-micron region was of the order of 0.1 microwatt per square centimeter. Assuming the sun is a black body at 6000 degrees and using Randall's[1] water spectrum, there should be about 0.3 microwatt per square centimeter. This agreement indicates that the water data may be used to compute the windows in this region to a fair degree of accuracy.

* This paper is based on a thesis submitted in partial fulfillment of the degree of Doctor of Philosophy to the Pennsylvania State College. It was supported in part by the United States Air Force.

[1] Randall, Dennison, Ginsburg, and Weber, Phys. Rev. 52, 160 (1937).

G2. Transition Probabilities II. Semi-Theoretical *f*-Numbers for Hydrogen Using the Dipole Velocity Operator.* HARRISON SHULL, *Iowa State College.*—The computations of transition probabilities for hydrogen by Mulliken and Rieke[1] using the LCAO MO and the AO methods have been repeated using the alternative velocity form of the transition moment operator. Calculations were carried through for both the Lyman bands ($^1\Sigma_g^+ \rightarrow {}^1\Sigma_u^+$) and the Werner bands ($^1\Sigma_g^+ \rightarrow {}^1\Pi_u$). In general the agreement is moderately good between the dipole length and dipole velocity methods. The dipole velocity method gives somewhat higher results for the Werner bands (0.49 instead of 0.38) but correspondingly lower results for the Lyman bands (0.18 instead of 0.24). As with the dipole length method, it is found necessary to use an effective Z value of 1.2 (the variation value) for the bonding orbital and a Rydberg form for the antibonding orbital in order to obtain reasonable results.

* Supported in part by the Ames Laboratory of the AEC.

[1] R. S. Mulliken and C. A. Rieke, Repts. Prog. Phys. 8, 231 (1941).

G3. Absorption and Emission Spectra of OH in Methane-Air Flames. HERBERT P. BROIDA, *National Bureau of Standards.*—In flames of premixed methane and air burning above

a one-half inch nozzle at atmospheric pressure, the rotational distributions of the $^2\Sigma \leftrightarrow {}^2\Pi$ transition (O↔O band) of OH in absorption and emission were measured and corresponding temperatures calculated. In addition, three separate line-reversal temperatures were determined by comparing the emission from added sodium, from added mercury, and from the $Q_1(5)$ rotational line of OH with a calibrated tungsten lamp. The rotational absorption and sodium reversal temperatures agree with calculated equilibrium temperatures to within the experimental errors of 50°C. The "rotational emission temperature" of the inner cone is approximately 3250°K at fuel to air ratios from 5.6 to 10.8 percent by volume; this is approximately 1100°C greater than the maximum equilibrium temperature. The abnormal distribution is interpreted to mean that excited OH radicals are formed in a chemical reaction with excess rotational energy, which is independent of the over-all energy release. The absorption (20 percent) of the $Q_1(5)$ line gives a concentration of 10^{14} OH radicals/cm³. A high resolution grating spectrometer with an attainable resolution of 0.55 cm^{-1} was used, but because of the weak intensities, the ultimate resolution was not obtained.

G4. Vibrational Constants of $Cl^{35}O_2$. J. B. Coon and E. Ortiz, *A. and M. College of Texas.*—A rough vibrational analysis of the violet absorption spectrum of ClO_2 vapor has been reported,[1] giving approximate values for the three fundamentals ν_i of both electronic states. The band system is described theoretically by $\nu = \nu_e + G'(v_1', v_2', v_3') - G''(v_1'', v_2'', v_3'')$. Fairly accurate values for the six zero-order frequencies ω_i' and ω_i'' and for all but three of the twelve anharmonic constants x_{ij}' and x_{ij}'' have now been obtained using all published data including infrared measurements as well as a few new data at the red end of the violet absorption region. The results in cm^{-1} are $\nu_e = 21369.5$, $\omega_1' = 722.0$, $\omega_2' = 296.1$, $\omega_3' = 804.4$, $x_{11}' = -3.45$, $x_{22}' = -1.3$, $x_{33}' = -3.6$, $x_{12}' = -4.6$, $x_{13}' = -9.4$, $x_{23}' = -3.1$; $\omega_1'' = 964.8$, $\omega_2'' = 451.8$, $\omega_3'' = 1127.3$, $x_{11}'' = -4.0$, $x_{22}'' = -0.8$, $x_{33}'' = -4.6$, $x_{12}'' = -2.2$, $x_{13}'' = -21.0$, $x_{23}'' = -3.1$. The values of x_{22}', x_{33}'', and x_{23}'' are not determined by the known data. It was, therefore, necessary to estimate them in order to determine the best values for the ω_i. For the most part, bands involving upper state quantum numbers v_1' greater than 5 were not used in evaluating the above constants, since a slight discontinuity is observed at this point. Predissociation has been reported to start at $v_1' = 6$.

[1] J. B. Coon, Phys. Rev. **58**, 926 (1940).

G5. Binding Energy and Dipole Moment of Alkali Halide Molecules. E. S. Rittner, *Philips Laboratories, Inc.*—A simple theory of alkali halide gas molecules in the spirit of Born-Mayer Lattice Theory is presented. The molecule is considered to be constituted of ions, each of which is polarized by the electrostatic field of the other. This deformation polarization has two important consequences: (1) the net dipole moment of the molecule becomes appreciably lower than that given by the product of the electric charge, e, and the internuclear separation, a; (2) the repulsion constants (determined from empirical data) become different from the corresponding constants for the crystal. The theory yields satisfactory results for the binding energy, vibration frequency, and dipole moment, μ, in all instances where necessary data are available. In cases where the internuclear distances are not known experimentally, they are calculated from the theory using experimental binding energies. It is possible to assign to the ions Goldschmidt-like radii, the sums of which reproduce reasonably well both the calculated and the observed internuclear distances. Finally, item (1) above explains why Pauling's criterion for the fraction of ionic character, $f = \mu/ea$, is not a very good measure of ionicity[1] for these completely ionic substances.

[1] G. Herzberg, I. "Spectra of diatomic molecules." *Molecular Spectra and Molecular Structure* (D. Van Nostrand Company, Inc., New York, 1950), second edition, p. 377.

G6. A Variation-Iteration Method for Calculating Energy Levels in Periodic Potentials. W. A. Bowers, *University of North Carolina.*—A variation-iteration method of attacking nuclear problems using eigenfunctions in momentum space has been developed by Svartholm.[1] The same method can be applied to the problem of a periodic potential; instead of an integral equation, one has then, in view of the periodicity, an infinite set of simultaneous equations. These can be made the basis of a variational calculation of the energy; in addition, an iterative procedure for improving the original functions can be formulated. To test the method, it has been applied to the one-dimensional model of Kronig and Penney.[2] In this case, starting with a constant wave function, the first iteration yields a function for which the various infinite series occurring in the expression for the energy can be summed exactly, and the energy, thus, found for the lowest state agrees with the exact value within less than 1 percent over a wide range of values of two parameters (depth of "valleys"; ratio of "valley" width to "hill" width). The method can be extended to higher states and also to three-dimensional problems.

[1] N. Svartholm, Thesis, University of Lund (1945).
[2] Kronig and Penney, Proc. Roy. Soc. (London) **130A**, 499 (1931).

G7. Infrared Absorption Study of Hydrogen Bonding Equilibria. Norman D. Coggeshall and Eleanor L. Saier, *Gulf Research and Development Company.*—A study has been made of hydrogen bonding equilibria using the infrared absorption due to the unassociated hydroxyl group. Sterically unhindered molecules associate in polymeric complexes. Agreement between theory and experiment obtained by the use of two equilibria constants, one for the dissociation of dimeric complexes and one for the dissociation of higher order complexes, is better than that obtained by the single equilibrium constant scheme of Kempter and Mecke.[1] These constants have been evaluated for a series of simple alcohols and phenols. If a phenol has one ortho position occupied by a large substituent, such as a *t*-butyl group, it will be sterically hindered and will associate almost entirely in dimeric complexes. The equilibrium constants for several such partially hindered phenols have been evaluated. Hydrogen bonding occurs between hydroxylated materials and proton acceptor compounds. Equilibrium constants have been evaluated for the systems of benzyl alcohol and methyl ethyl ketone and of benzyl alcohol and 1,4-dioxane. At higher concentrations of the proton acceptor materials, an anomalous effect which results in an apparent strengthening of the inter-molecular bonding between unlike molecules is observed.

[1] H. Kempter and R. Mecke, Z. physik. Chem. **46**, 229 (1941).

G8. A Collision Theory of Chemical Kinetics. F. A. Matsen, *The University of Texas.*—The Schroedinger equation for the reacting system is expressed in nuclear coordinates only. Its solutions are expanded as products of internal wave functions and initially undetermined functions of the relative displacements of the reaction products. With a simplifying assumption about the rotational functions and with the familiar techniques using Green's function, there is obtained, to the first Born approximation, an expression for the probability of transition from a given reactant state to a given product state for a unit incident flux. On summing over the product states, averaging over the reactant states, and adjusting for the actual flux and number of scattering centers, there is obtained an expression for the average rate of the chemical reaction similar to that obtained by Golden[1] from first-order time-

dependent perturbation theory. The effect of higher approximations to the collision theory will be briefly discussed.

[1] S. Golden, J. Chem. Phys. **17**, 620 (1949).

G9. On the Formalism of Thermodynamic Fluctuations. R. F. GREENE,* *University of Pennsylvania.*—The Einstein expression for the probability of fluctuations δx^1, δx^2, $\cdots$, in the extensive parameters of a thermodynamic system, i.e.,

$$p=\exp[(\Sigma_{i,k}S_{ik}\delta x^i\delta x^k+\text{higher terms})/2k],$$

where

$$S_{ik}\equiv\partial^2 S/\partial\langle x^i\rangle_{Av}\partial\langle x^k\rangle_{Av},$$

has been used almost exclusively. For ease in calculation, it has been the practise to drop the higher terms, apparently thereby introducing an error usually considered to be small. This apparent error has been of interest in several connections, notably in critical fluctuations. All the extensive parameter fluctuation moments, however, may be calculated by an exact method based upon the canonical formalism of statistical mechanics. It can then be shown that the Einstein expression, with the higher terms formally omitted, yields the second moments with no error.

* Sponsored, in part, by the ONR.

G10. Ionization by Electron Impact in CO, N_2, NO, and O_2. H. D. HAGSTRUM, *Bell Telephone Laboratories.*—All the ionization processes which occur on electron impact in CO, N_2, NO, and O_2 have been restudied with a special mass spectrometer in which mass, appearance potential, and initial kinetic energy (by retarding potentials after mass analysis[1]) can be determined simultaneously. Results agree well with kinetic energy determinations based on velocity dispersion in the analyzer,[2] transverse deflection in the analyzer and discrimination at the exit slit,[3] and retarding potential measurements without mass analysis.[4,5] Appearance potential measurements generally agree very well with previous measurements.[2,4,5] In oxygen the present work reveals structure in the appearance potential data missed before[3] and brings agreement with the accepted values of $D(O_2)$ and $EA(O)$. The new measurements in CO, N_2, and NO appear to strengthen the "electron impact position" regarding controversial energetic quantities related to these molecules,[6] indicating again that $D(CO)=9.61$ ev, $L(C)=136$ kcal, $D(N_2)=7.38$ ev, $D(NO)=5.30$ ev, $EA(O)=2.2$ ev, and that the O^- ion has an excited state very near the positive energy continuum.

[1] R. E. Fox and J. A. Hipple, Rev. Sci. Instr. **19**, 462 (1948).
[2] H. D. Hagstrum and J. T. Tate, Phys. Rev. **59**, 354 (1941).
[3] C. E. Berry, Phys. Rev. **78**, 597 (1950).
[4] W. W. Lozier, Phys. Rev. **44**, 575 (1933); ibid. **45**, 850 (1934); ibid. **46**, 268 (1934).
[5] E. E. Hanson, Phys. Rev. **51**, 86 (1937).
[6] H. D. Hagstrum, Phys. Rev. **72**, 947 (1947); J. Chem. Phys. **16**, 848 (1948).

G11. A Model of an Imperfect Gas. T. H. BERLIN AND L. WITTEN, *The Johns Hopkins University.*—A volume V containing N particles is divided into cells of volume $v=V/N$. The partition function can be expressed as $\sum'_{\{n_i\}} I(\{n_i\})$, where n_i represents the number of particles in the ith cell. $I(\{n_i\})$ is the integral of the Boltzmann factor over all spatial configurations of the particles consistent with a given $\{n_i\}$ weighted by the probability of the set $\{n_i\}$. The partition function is evaluated in the limit $N\to\infty$, $V\to\infty$, and v finite assuming that: (1) particles in a given cell are at the cell center; (2) the sum over the lattice points $\{n_i\}$ can be replaced by a special multiple integral; (3) fluctuations are small; and (4) surface effects are negligible. It is found that the limiting free energy is a nonanalytic function of v. For temperatures lower than a critical temperature, T_c, the $p-v$ curve consists of *three* pieces. The two discontinuities are in d^2p/dv^2, not in dp/dv. For $T>T_c$, the $p-v$ curve is regular. The existence of critical phenomena requires that $U(r)$, the potential energy of a pair of particles, have the *shape* of the usual molecular potential.

G12. Effect of a Non-linear Impedance on Narrow Band Noise.* J. L. MCLUCAS AND R. C. RAYMOND, *The Pennsylvania State College.*—An experimental program was undertaken to check the ability of the theory of Middleton[1] to predict the power spectrum of the current flowing in a nonlinear impedance excited by a noise voltage and to compare this power spectrum with the power spectrum of the current in the same nonlinear element excited by a continuous wave voltage of the same power level as the noise excitation. It was found that the Middleton theory predicts the general features of the output for the noise case. No appreciable differences in power level between the harmonic components of the output current for noise excitation and those for continuous wave excitation were found. A c-w signal at 1.6 mc/s or a narrow band of noise centered at the same frequency were used to drive a type 1N34 crystal diode. The crystal output was passed through attenuators (for isolation purposes) to a radio receiver which was used to analyze the radiofrequency components of the output. The low frequency components were studied with an audiofrequency wave analyzer.

* This paper is taken from a thesis submitted to the Physics Department, The Pennsylvania State College.
[1] D. Middleton, Quart. Appl. Math. **5**, 445 (1948).

G13. A Formula for Multiple Scattered Electrons.* C. H. BLANCHARD AND U. FANO, *National Bureau of Standards.*—The theory of multiple scattering[1] leads to a formula which relates the progressive loss of memory of the original direction to the accompanying energy dissipation by inelastic collisions. Calling θ the angle between the direction of an electron of kinetic energy T and its direction at the initial energy T_0 and taking an average over all electrons with energy T, we have:

$$\langle\cos\theta\rangle_{Av}=[(T/T_0)(T_0+2mc^2)/(T+2mc^2)]^{(Z/2)(C/B)};$$

$Z=$atomic numbers of scatterer, $B=-(dT/dx)/(2\pi NZe^4/mv^2)$ stopping number, $C=(p^2v^2/2Z^2e^4)\int_{4\pi}\sigma_{el}(T,\ \Theta)(1-\cos\Theta)d\Omega=\int_{-1}^{1}[\sigma_{el}(T,\ \Theta)/\sigma_{Ruth}(T,\ \Theta)]d\cos\Theta/(1-\cos\Theta)=$"scattering number." The equation for $\langle\cos\theta\rangle_{Av}$ results from an integration which assumes C/B independent of T. Both C and B vary logarithmically with T, but their ratio remains remarkably constant and a little greater than $\frac{1}{2}$, all of which follows from their representation as angular integrals. Using $\sigma_{el}=(Z^2e^4/p^2v^2)[1-\cos\Theta+(Z^1/2\ 137^2)(mc/p)^2]^{-2}$, we find for carbon at 50 and 1000 kev, $C/B=0.52$ and 0.55, and for lead, respectively, 0.64 and 0.63; use of the Mott σ_{el} would give a less constant C/B.

* Supported by the ONR.
[1] See e.g. H. W. Lewis, Phys. Rev. **78**, 526 (1950).

G14. Integro-Causality and Interaction with a Memory in a Divergence-Free Field Theory. FREDERIK J. BELINFANTE, *Purdue University.*—The Schrödinger functional Ψ describing a physical situation at time t depends not only on t and occupation numbers N but also on variables labeling experimental evidence determining the initial value of Ψ, say on time t_0 of last experiment. A new experiment by observer A at t_1 changes for A the prediction $\Psi(t_1, t_0)$ into a new initial value $\Psi(t_1, t_1)$. If a long-range causal connexion $\Psi(t, t_0)=U(t, t_0)\Psi(t_0, t_0)$ is given with unitary matrix U, then there is no longer a reason why $U(t_2, t_1)U(t_1, t_0)$ should equal $U(t_2, t_0)$. Thus, the Schrödinger equation is generalized to $ih\partial\Psi(t, t_0)/\partial t=B(t, t_0)\Psi(t, t_0)$ with hermitian operator B depending also on t_0, thus generalizing "immediate causality" to "integro-causality." $B(t, t_0)$ has a "memory back to t_0, which enables us to postulate that B has vanishing matrix elements $\langle N'(t')|B(t, t_0)|N''(t'')\rangle$ to and from Feynman diagrams "unallowable" between t_0 and t. "Unallowable" are all

self-energy parts, vertex parts, high order scattering parts or other possible causes of divergencies. Lamb-shift effects etc. are incorporated as part of interaction and of commutation relations directly in matrix element factors corresponding to diagram vertices and lines.

G15. Sampling Methods for Fourier Transform; Computations on *X-RAC*.* RAY PEPINSKY, *The Pennsylvania State College*.—In x-ray analysis, the relationships between the scattering function and the distribution of scattering material are those of Fourier mates. Thus, any device which can transform from scattering to density space can operate equally well in the converse direction. In computing density functions, *X-RAC* utilizes values of the scattering function—obtained at nodes of the reciprocal lattice by x-ray scattering measurements on a crystal—as Fourier coefficients and computes the transform of this as a periodically repeated contour map of the density function. But the machine can equally well sample an assumed density function, on a periodic sublattice of the unit cell, and compute the transform of this as a (periodically repeated, continuous) structure factor map. Sampling of this continuous structure factor on the nodes of the reciprocal lattice then gives discrete structure-factor values, which can be compared in amplitude with those observed by x-ray scattering from the crystal. Fineness of sampling is essential to reduction of overlapping of the resulting periodically reproduced continuous Fourier transforms, because the transform will be set down at points reciprocal to the sampling sublattice. If the sublattice is sufficiently fine, furthermore, the density function can be approximated by spherical atoms positioned on nearest sampling nodes. A method is described for extension of the number of sampled values—i.e., Fourier coefficients—any synthesizer can accommodate.

* Development supported by ONR.

FRIDAY AFTERNOON AT 2:15

Mellon Institute Auditorium

(W. SHOCKLEY presiding)

Symposium (DSSP) on Luminescence, Photo-Effect, Electron, and Exciton Migration

H1. Photo-luminescence of Inorganic Solids. J. H. SCHULMAN, *Naval Research Laboratory*. (40 min.)
H2. Basic Physical Processes in Crystal Counters. H. KALLMANN, *New York University*. (40 min.)
H3. Exciton-Induced Photoelectric Effects in Alkali Halides. L. APKER AND E. TAFT, *General Electric Company*. (40 min.)

FRIDAY AFTERNOON AT 2:00

Bureau of Mines

(F. G. BRICKWEDDE presiding)

Symposium (DCP) on Barriers to Internal Rotation of Molecules and Related Stereo-Isomerism

I1. Introduction; Review of the Theoretical Calculation of Barriers to Internal Rotation of Molecules. G. E. KIMBALL, *Columbia University*. (30 min.)
I2. The Contributions of Thermodynamics and Statistical Mechanics as to the Problem of Barriers Hindering Internal Rotation. J. G. ASTON, *Pennsylvania State College*. (30 min.)
I3. Rotational Isomerism by the Spectroscopic Method. H. J. BERNSTEIN, *National Research Council of Canada*. (40 min.)
I4. Strain and Steric Effects in Tautomeric Structures of Several Normal and Cyclic Hydrocarbon Molecules and Their Simple Derivatives. C. W. BECKETT, *National Bureau of Standards*. (30 min.)
I5. Some Microwave Aspects of Hindered Rotation in Methyl Alcohol. D. G. BURKHARDT, *University of Colorado*. (30 min.)

FRIDAY AFTERNOON AT 2:15

Mellon Institute Social Room

(J. E. GOLDMAN presiding)

Metals

J1. The Analysis of Solids with the Mass Spectrometer. J. G. GORMAN,* E. A. JONES, AND J. A. HIPPLE, *National Bureau of Standards*.—Quantitative analyses of solid samples have been successfully performed with a mass spectrometer using a high frequency spark in vacuum. The ions from the source pass through an energy filter and enter a magnetic

analyzer, where the various masses are sorted out by varying the magnetic field and scanning the ions across an exit slit. The current to this ion collector fluctuates through a wide range because of the instability of the spark source. To compensate for these fluctuations, a monitoring electrode is placed at the entrance to the magnetic field; and, as the various ions are scanned across the exit slit, the ratio of the current passing through the exit slit to that received by the monitor is recorded. Since these two collectors receive currents from the same source, the fluctuations of this source are effectively nullified in comparing the ion currents corresponding to different masses. The effectiveness of the method will be demonstrated with some results on the chemical composition of six stainless steel samples. These samples vary in chromium and nickel concentration from a fraction of 1 percent to 25 percent, and the calibration of the instrument was found to be linear over this range.

* Present address: Carnegie Institute of Technology, Pittsburgh, Pennsylvania.

J2. Atomic Displacements and Crystallite Orientations in the Deformation of Single Crystals. B. L. AVERBACH AND B. E. WARREN, *M.I.T.*—Single crystals of a Cu – 2 percent Si alloy have been deformed by cold rolling in the (110) [112] direction. Rocking curves, obtained by means of a double-crystal spectrometer, indicated that the annealed crystals had a half-maximum width of approximately 8 minutes (intensity *vs* crystal setting). After a cold reduction of 50 percent, the mean orientation of the crystal remained unchanged; but the half-maximum width of the rocking curve was increased to 168 minutes. Average atomic displacements introduced by cold rolling were evaluated by means of a Fourier analysis[1] of intensity curves (intensity *vs* chamber setting, 2θ) obtained with monochromatic radiation and a single-crystal spectrometer. The intensity peaks were considerably broadened by the plastic deformation, with a large part of the broadening appearing in the form of elongated tails. The plastically deformed crystals showed considerable recovery on annealing at 300°C. The intensity peaks (intensity *vs* 2θ) sharpened, but the double crystal rocking curves did not decrease in width. This indicates that the spread in crystallite orientation introduced by the plastic deformation is not removed during recovery, although considerable strain relief may occur in each of the individual crystallites. No macroscopic polygonization was observed under these recovery conditions.

[1] B. E. Warren and B. L. Averbach, J. Appl. Phys. 21, 595 (1950).

J3. The Effect of Pile Irradiation on the Stress-Strain Curve of Copper. T. H. BLEWITT AND R. R. COLTMAN, *Oak Ridge National Laboratory.*—Two single crystals of the same orientation were grown by the Bridgman method in a high vacuum. These specimens were grown to conform with A.S.T.M. specifications of standard ¼" tensile specimens. One of the specimens was then sealed in an evacuated quartz tube and exposed in the Oak Ridge pile to a fast neutron flux of 1.8×10^{19} nvt. Stress strain curves on both crystals were subsequently measured. The critical shear stress was found to be 0.241 Kg/mm² for the unirradiated and 1.938 Kg/mm² for the irradiated sample.

J4. The Change in Resistivity of Copper by Low Temperature Annealing. T. H. BLEWITT, W. TAYLOR, AND R. R. COLTMAN, *Oak Ridge National Laboratory.*—Frederick Seitz[1] has suggested that atomic vacancies and interstial atoms can be generated by solids and that dislocations act as sources and sinks for lattice vacancies and interstial atoms. Measurements of the ionic conductivity by Gyulai and Hartly[2] show that imperfections created by plastic deformation are annihilated in one hour at 38°C in NaCl. Samples of polycrystalline copper cold-worked at liquid nitrogen temperatures show a decrease in resistivity upon annealing at 20°C of approximately one-third of the total increase in resistivity induced by the plastic deformation. It was found that a similar effect was also observed by a short anneal (½ hour) at dry ice temperatures. Apparently, if this effect is due to the annihilation of vacancies and interstials, the relaxation time for the annihilation of these imperfections is comparatively short in metals compared to that of ionic crystals. The results for the room temperature annealing were obtained independently of the research of Molenar and Aarts[3] are in agreement with their results.

[1] Conference on Plastic Properties of Solids, Carnegie Institute of Technology, Pittsburgh, Pennsylvania.
[2] Gyulai and Hartly, Z. Physik 51, 378 (1928).
[3] Molenar and Aarts, Nature (October, 1950).

J5. Recovery of Internal Friction in Alpha-Brass. HERBERT I. FUSFELD, *Frankford Arsenal.*—Fine-grained annealed specimens of 70–30 cartridge brass were given various amounts of cold-working, then annealed at temperatures below the recrystallization temperature. Internal friction measurements were conducted continuously during the anneals. Among the general features of the curves are the following. (a) Extensive recovery occurs within a matter of minutes. (b) The recovery curves at a given temperature intersect, so that the order of the curves depends on the time of measurement. (c) The data indicates an equivalent activation energy for the process considerably lower than in atomic interchange processes as diffusion. (d) A plot of recoverable internal friction (instantaneous minus final value) *versus* time is a straight line on a log-log scale, so that the internal friction falls off inversely as a simple power of time. The exponent has a range of about 0.2 to 0.8.

J6. Heat Conduction in Alloys at Low Temperatures. J. ZIMMERMAN,* *Carnegie Institute of Technology.*—Thermal and electrical conductivity measurements have been made on a number of copper-nickel and stainless-steel alloys in the temperature region between 2.6 and 80°K. Cryostat used was a Simon-type helium liquefier which functioned also as a cryostat for the liquid-hydrogen and liquid-nitrogen temperature regions. Heat was supplied electrically to one end of each specimen, and the difference of temperature between two points was measured by means of two gas thermometers connected to a differential pressure indicator. It was found that the Wiedemann-Franz ratio for these alloys generally exceeds the theoretical value of 2.45×10^{-8} watt-ohm/deg², except in the liquid-helium region, where it approaches the theoretical value quite closely for three of the specimens (hard-drawn monel and two stainless steels). Also, it was found that annealed specimens have about the same electrical conductivity but greater thermal conductivity than hard-drawn specimens of the same material. These results suggest an appreciable lattice contribution to the thermal conductivity, at least in the case of the annealed specimens.

* The author started this work as a Gerard Swope fellow and continued it with assistance by the ONR and the Research Corporation.

J7. Alternating Hall Voltage Measurement.* D. B. BARKER, E. J. HUIBREGTSE, AND W. C. CALDWELL, *Iowa State College.*—With a constant magnetic field and an alternating primary current,[1] an alternating Hall voltage is obtained which may be amplified conveniently and which eliminates thermal emf if the frequency is sufficiently high for a given thermal conductivity of the sample. As a compromise between noise and heat flow considerations, a frequency of 10 cycles per second was chosen. The sign of the Hall coefficient may be determined by displaying the primary current and the Hall voltage on an oscilloscope by means of an electronic switch. The problems of noise and of induction between the primary circuit and the detection circuit will be discussed.

* This work was performed in the Ames Laboratory of the AEC.
[1] W. F. Leverton and A. J. Dekker, Phys. Rev. 80, 732 (1950).

J8. Electrical Properties of Sodium Wolfram Bronze.* E. J. HUIBREGTSE, D. B. BARKER, AND G. C. DANIELSON, *Iowa State College.*—With the addition of sodium atoms the ferroelectric insulator WO_3 acquires metallic properties. We have grown single crystals of Na_xWO_3 using a method developed at Linde Air Products. These crystals have been chemically analyzed yielding $x=0.68$. The electrical conductivity at 0°C is $(5.3\pm0.7)10^3$ ohm^{-1} cm^{-1} and decreases linearly with increasing temperature in the range -180°C to 40°C. The Hall coefficient[1] is $(-5.3\pm0.8)10^{-4}$ cm^3/coulomb and decreases slowly with decreasing temperature. This value indicates one electron carrier for each sodium atom added to the crystal. On Pauli's theory of paramagnetism the calculated magnetic susceptibility is 0.51. The value observed by Stubbin and Mellor[2] is 0.45 ± 0.003. The mobility of the electrons is low compared with the mobility in most metals.

* This work was performed in the Ames Laboratory of the AEC.
[1] See preceding paper by Barker, Huibregtse, and Caldwell.
[2] P. M. Stubbin, and D. P. Mellor, Proc. Roy. Soc. N. S. Wales **82**, 225 (1948).

J9. Experimental Evidence of Relaxation during Diffusionless Phase Changes of Single Crystal Beta-Au-Cd Alloys Containing 47.5 Atomic Percent Cd. L. C. CHANG AND T. A. READ, *Columbia University.**—The β-Au-Cd alloy containing 47.5 atomic percent Cd (CsCl structure, 2 atoms per unit cell, $a_0=3.317k\bar{X}$ units) transforms by a diffusionless mechanism to β' (orthorhombic structure, 4 atoms per unit cell, $a=3.148$, $b=4.755$, $c=4.855$ $k\bar{X}$ units) on cooling to about 60°C and the reverse diffusionless transformation from β' to β takes place when the β'-alloy is heated to about 70–80°C. The transformation takes place typically in well-annealed crystals by the slow movement of an interface between the two phases from one end of the specimen to the other until transformation is complete. It was found that by holding the interface at a given position of the specimen (on cooling) for a certain length of time t at a given temperature T, the same interface (on reheating at a constant heating rate) stops at exactly the same position for a time interval t' and then proceeds with a jerky motion. Preliminary results show that t' varies both with t and T, suggesting that the relaxation phenomenon is diffusion controlled, for example, by the diffusion of foreign atoms to the interface. More detailed studies of this phenomenon are still in progress.

* This work was supported by the AEC.

J10. Relaxation Processes in the β′-Phase of the Alloy Au Cd. D. S. LIEBERMAN, T. A. READ, AND L. C. CHANG, *Columbia University.**—Single crystals of the Au Cd alloy containing 47.5 atomic percent Cd were grown by the Bridgman method from 99.95 percent purity gold and 99.99 percent purity cadmium and were found to have a body centered cubic structure in the high temperature phase.[1] A diffusionless phase change results in an orthorhombic phase below the transformation temperature. For certain orientations of the orthorhombic domains in the low temperatures phase, the specimen exhibits a rubber-like behavior.[2,3] Immediately after transformation, however, the specimen is soft; and it has been found that the rate of appearance of rubber-like behavior is dependent on the temperatures, the time, and the strains imposed on the specimen. The velocity of sound in the low temperature phase was also found to exhibit a time-temperature dependence characteristic of diffusion phenomena.

* This work was supported by AEC.
[1] L. C. Chang and T. A. Read, J. Metals (January, 1951).
[2] A. Olander, Z. Krist. **83A**, 145 (1932).
[3] C. Benedicks, Arkiv Mat. Astron. Fysik **27A**, No. 18 (1940–1941).

J11. Short Range Order in CuAu. B. W. ROBERTS, JR., *M.I.T.** (*Introduced by* B. E. WARREN).—Diffuse x-ray scattering from the 100 face of a CuAu single crystal has been measured throughout a volume in reciprocal space sufficient to give the short range order parameters. Bent-quartz monochromated copper radiation was used with a Ni-Al balanced filter and detected with a G-M counter. Temperature diffuse scattering was subtracted out by extrapolation from three temperatures below T_c. The short range order diffuse peaks are roughly spherical in shape when considered in reciprocal space. The 100 and 300 peaks are found to be displaced away from the origin, suggesting a tendency to a layer type ordering above T_c. An assymmetry around the 200 and 400 fundamental reflections has been observed and shown to result from the randomness of position of the Cu and Au atoms with their different radii and scattering factors. Short range order parameters are given for crystals quenched from 500°C, and held at temperatures of 425°C and 525°C. The values of the short range order coefficients are similar to those found for Cu_3Au.

* Research sponsored by the ONR.

J12. A Refinement of the Ineffectiveness Concept in the Theory of the Anomalous Skin Effect in Metals.* PAUL M. MARCUS, *University of Illinois.*—The electromagnetic behavior of a metal at low temperatures and high frequencies may be roughly described by the ineffectiveness concept,[1] which introduces the effective conductivity $\sigma_e=(\delta_e/l)\sigma$ (δ_e=effective skin depth of field, l=mean free path of electrons, σ=dc conductivity). This formula yields dimensionally correct, order-of-magnitude values of surface resistance, R, and surface reactance, X, but fails to reveal important physical detail and is based on physical arguments which do not emphasize the dominant contribution to the electric current. The modified formula $\sigma_e=(\sigma/2ikl)(1+p)$ (κ=complex propagation constant of field, p=electron reflection coefficient at metal surface) is derivable by simple argument which considers electrons to contribute effectively to the current in proportion to the drift velocity acquired in the skin layer. The correct relation $X=R\sqrt{3}$ and the effect of the reflection coefficient now follow. More precise considerations of the kinetics of electron motions in an exponential field give formulas agreeing more closely with rigorous results.[2] Although the rigorous field is not exponential, these calculations justify an exponential as a reasonable approximation.

* This work has been assisted by the ONR.
[1] A. B. Pippard, Proc. Roy. Soc. (London) **A191**, 385 (1947).
[2] G. E. H. Reuter and E. H. Sondheimer, Proc. Roy. Soc. (London) **A195**, 336 (1948).

FRIDAY EVENING AT 8:15

Syria Mosque

Concert of the Pittsburgh Symphony Orchestra

SATURDAY MORNING AT 9:30

Mellon Institute Auditorium

(J. H. VAN VLECK presiding)

Symposium (DSSP) on Ferromagnetism and Antiferromagnetism

K1. Some Aspects of Gyromagnetic Resonance in Ferrites. H. B. G. CASIMIR, *Philips Research Laboratories, Eindhoven.* (40 min.)

K2. Antiferromagnetism and the Néel Theory of the Ferrites. CHARLES KITTEL, *Bell Telephone Laboratories.* (40 min.)

K3. Magnetic Resonance Absorption in Antiferromagnetic Materials. L. R. MAXWELL, *National Bureau of Standards.* (40 min.) *Naval Ordnance Laboratory.* (40 min.)

K4. Magnetic Structure Studies by Neutron Diffraction. C. G. SHULL, *Oak Ridge National Laboratory.* (40 min.)

SATURDAY MORNING AT 9:30

Bureau of Mines

Beginning of the Symposium (DCP) on Statistical-Mechanical Aspects of Chemical Physics

L1. Introduction to the Symposium. J. O. HIRSCHFELDER, *University of Wisconsin.* (10 min.)

L2. Methods of Calculating the Equation of State. J. E. MAYER, *University of Chicago.* (30 min.)

L3. Some Problems in the Kinetic Theory of Gases. J. O. HIRSCHFELDER AND C. F. CURTISS, *University of Wisconsin and Naval Research Laboratory.* (30 min.)

L4. Solution of Some Rarefied-Gas Flows Using the Boltzmann Equation. HAROLD GRAD, *New York University.* (30 min.)

L5. Delta-Function Methods in Statistical Mechanics. ELLIOT MONTROLL AND T. BERLIN, *New York University.* (30 min.)

SATURDAY MORNING AT 9:30

Cathedral of Learning, Room 324

(E. C. CREUTZ presiding)

Nuclear Physics

M1. Electron Mobilities and Delay Times in Geiger-Mueller Counters.* ALDEN STEVENSON,† *Bartol Research Foundation (Introduced by* C. E. MANDEVILLE*).*—Using a coincidence counting arrangement to measure transit times of electrons in G-M counter gases, electron mobilities in argon-butane and argon-ether mixtures have been obtained. At field strengths corresponding to distances up to as little as three millimeters from the wire, the mobility in the argon-ether mixture is more than twice as great as that in the argon-butane mixture, suggesting more rapid transit times for argon-ether G-M tubes. The measurement of time intervals between coincident discharges in two argon-ether counters of diameter 1.5 cm shows that the *maximum* delay time is $<10^{-7}$ sec.

* Assisted by the joint program of the ONR and AEC.
† At present at the University of Virginia.

M2. Delay Times and Coincidence Resolving Times for G-M Counters.* C. E. MANDEVILLE, *Bartol Research Foundation.*—The results of the preceding abstract will be discussed, and their bearing upon data already published[1] will be considered. The mobility measurements agree with earlier observations[2] of genuine coincidence loss that the argon-butane mixture is unsatisfactory for a double coincidence resolving time of less than about 0.2 microsecond, whereas the argon-ether mixture can be used without loss at 0.08 microsecond in G-M counters of diameter 1.5 cm. The delayed coincidence measurements of the preceding abstract were made with glass-Aquadag counters chosen at random from a supply of counters used by this writer during the last four years for beta-gamma, gamma-gamma, and beta-beta coincidence measurements.

* Assisted by the joint program of the ONR and AEC.
[1] C. E. Mandeville and M. V. Scherb, Phys. Rev. **73**, 90 (1948).
[2] C. E. Mandeville and M. V. Scherb, unpublished data (1947).

M3. On the Measurement of Times of 10^{-10} Second between Ionizing Events.* S. DE BENEDETTI AND H. J. RICHINGS, *Carnegie Institute of Technology.*—By means of scintillation counters in coincidence we were able to detect the time of flight of gamma-rays over a distance of 3 cm. A source of annihilation radiation was located half-way between two scintillation counters (either stilbene or terphenyl in xylene, with 5819 photo-multipliers), the pulses of which, without amplification and after shaping with a shorted line, were fed through cables of various length to a coincidence circuit of 10^{-9}-sec resolving time. In a typical experiment the source was displaced 3 cm along the line joining the counters

and an easily detectable shift in the coincidence curve (counts *versus* cable length) was observed. The delay of 2×10^{-10} sec introduced by displacing the source produced a variation of ≈50 percent in the counting rate along the slope of the coincidence curve. Under the same conditions a delay of 5×10^{-11} sec would produce a variation of 10 percent.

* This work was done under the auspices of the AEC.

M4. Beta-Ray Spectroscopy with Anthracene.* JAMES P. PALMER.†—A scintillation coincidence spectrometer in block form is described. This device was constructed so that it could be used as a scintillation counter without coincidence. A theoretical analysis of the response of the instrument to monokinetic beta-particles is reported. Formulas for correcting the experimental data for the poor resolution of the instrument are discussed. By beta-gamma-coincidence spectrometry, the lower beta-spectrum of Rb^{86} has been found to have an end point of 0.67 kev within about 15 percent. At a maximum x-ray energy of nominally 70 Mev, using the Iowa State College synchrotron to produce Ag^{112} and Ag^{113} from Cd^{113} and Cd^{114}, respectively, by a gamma-proton reaction, the ratio of the cross section of Ag^{113} to Ag^{112} is found to be 1.5. Beta-end-point determinations for Ag^{112} and Ag^{113} have been found to be 4.2 Mev and 2 Mev, respectively, within 8 percent.

* Work performed in the Ames Laboratory of the AEC.
† Now at Oak Ridge National Laboratory.

M5. The Pairing Effect in Nuclei and the Beta-Labile Elements. TRUMAN P. KOHMAN, *Carnegie Institute of Technology.*—Glueckauf[1] has shown that in the region of the heaviest elements the pairing energy of protons exceeds that of neutrons by 0.2 Mev on the average. Statistical examination of the beta-stable odd-A nuclides according to parity of Z shows that this situation is probably general except for light elements. A small part of the effect can be accounted for by differences in the spacing of individual-particle levels of protons and neutrons in the same potential well[2] when their numbers are different. The major part is probably due to the greater magnetic moments of protons, resulting from the orbital charge motion, causing stronger magnetic dipole interaction[3] in pairing. The beta-lability of $_{43}$Tc and $_{61}$Pm is attributable to the combined action of this effect, suggested *ad hoc* by Kowarski[4] and the increased slope of the beta-stability curve in regions near closed neutron shells, as described by Aten.[5]

[1] E. Glueckauf, Proc. Phys. Soc. (London) **61**, 25 (1948).
[2] L. Feenberg, Revs. Modern Phys. **19**, 239 (1947).
[3] L. Feenberg, Phys. Rev. **76**, 1275 (1949).
[4] L. Kowarski, Phys. Rev. **78**, 477 (1950).
[5] Aten, Science **110**, 260 (1949).

M6. A New Rare Earth Alpha-Emitter.* K.-H. SUN, F. A. PECJAK AND B. JENNINGS, *Westinghouse Research Laboratories,* AND A. J. ALLEN AND J. F. NECHAJ, *University of Pittsburgh.*—The only natural existing alpha-emitter in the lanthanide rare earth region has been recently identified[1,2] as $_{62}Sm^{147}$. Thompson *et al.*[3] have produced three alpha-emitting nuclides with half-lives of 7-min, 20-min, and 4-hr by bombarding Gd_2O_3 and Dy_2O_3 with 200-Mev protons. The 4-hr nuclide has since been identified[3] as $_{65}Tb^{149}$. We have observed a new alpha-emitter with 7.0-hr half-life by bombarding a thin film of Sm_2O_3 with 30-Mev alphas. Since the same activity was not produced by proton (8 Mev) and deuteron (15 Mev) bombardments on Sm_2O_3, the new nuclide is apparently not $_{63}$Eu. From the general considerations of reaction products of alpha-bombardment and also of shell model and alpha-systematics,[4] the new nuclide is probably $_{64}Gd^{149}$ or $_{64}Gd^{148}$.

* Assisted by the joint program of the ONR and AEC.
[1] B. Weaver, Phys. Rev. **80**, 301 (1950).
[2] Rasmussen, Reynolds, Thompson, and Ghiorso, Phys. Rev. **80**, 475 (1950).
[3] Thompson, Ghiorso, Rasmussen, and Seaborg, Phys. Rev. **76**, 1406 (1949).
[4] Perlman, Ghiorso, and Seaborg, Phys. Rev. **77**, 26 (1950).

M7. Relative Cross Sections and Excitation Characteristics of 6.5-Mev Triton Reactions on Cu and Ag. D. N. KUNDU AND M. L. POOL, *Ohio State University.*—A triton beam (6.5 Mev) in the cyclotron bombarded stacks of foils (0.0006″ Ag and 0.001″ Cu). The reactions (t, d), (t, p), (t, n), and (t, He^3) were produced and showed quite varied energy dependence. The thresholds in terms of the number of the foil up to which appropriate activities were traced are: $Ag^{109}(t, d)$ foil 4; $Ag^{109}(t, p)$, $Ag^{109}(t, He^3)$, $Cu^{65}(t, p)$, $Cu^{63}(t, d)$, and $Cu^{63}(t, n)$ foil 2; $Cu^{63}(t, He^3)$ foil 1. Relative cross sections at 6.5 Mev for Cu $\sigma^{65}(t, p):\sigma^{63}(t, He^3):\ \sigma^{63}(t, d):\sigma^{63}(t, n) = 10:6:11:64$, and for Ag $\sigma^{109}(t, p):\sigma^{109}(t, He^3):\ \sigma^{109}(t, d) = 10:1:17$. The $Ag^{109}(t, d)$ excitation curve rises steeply at the low energy beginning and then very slowly up to 6.5 Mev. The shape is different from that expected for compound nucleus processes and also from usual (d, p) excitation curves. This indicates a pronounced O−P process with the compound nucleus formation gradually taking over. A comparison of (t, p) reactions in Ag, Cu, Al, and C shows that in general this cross section increases very rapidly as Z diminishes. The marked polarization of the triton makes it plausible that the two neutrons in (t, p) reactions are mostly captured simultaneously as a dineutron. The comparatively higher thresholds for (t, He^3) reactions in both cases are consistent with their endothermic nature.

M8. Neutrons from Deuterons on Silicon 28.* C. P. SWANN AND C. E. MANDEVILLE, *Bartol Research Foundation.*—A thick target of isotopic $Si^{28}O_2$ was irradiated by deuterons of energy 1.4 Mev, supplied by the Bartol Van de Graaff statitron. A single group of neutrons at $Q = 0.36\pm0.05$ Mev was observed by the recoil proton-photographic plate technique. Using the mass values given by Bethe in 1947, the mass of P^{29} is calculated to be $28.9928\pm6\times10^{-4}$ mu. The data of Peck[1] would now indicate a level in P^{29}, at 1.16 ± 0.11 Mev. Measurements relating to $Si^{29}(D, n)P^{30}$ and $Si^{30}(D, n)P^{31}$ are in progress.

* Assisted by the joint program of the ONR and AEC.
[1] R. A. Peck, Jr., Phys. Rev. **73**, 947 (1948).

M9. Apparatus for Precision Scattering Measurements.* RALPH ELY, JR., A. J. ALLEN, J. ARTHUR, R. S. BENDER, H. J. HAUSMAN, L. A. PAGE, AND E. M. REILLEY, *University of Pittsburgh.*—A schematic layout of the equipment constructed for precision scattering studies at the Radiation Laboratory of the University of Pittsburgh is presented. Two 6-ton magnets are used to direct the cyclotron beam through 35 feet of evacuated duct to the scattering chamber in a shielded room, providing a rather monoenergetic beam of relatively high intensity. The beam energy can be varied by use of absorbing foils. A third magnet analyzes the scattered particles. The University of Pittsburgh cyclotron provides 8-Mev protons, 16-Mev deuterons, and 32-Mev alpha-particles. Available proton beam and energy resolutions will be given.

* Assisted by the joint program of the ONR and AEC.

M10. Performance of Analyzer Magnets.* LORNE A. PAGE, A. J. ALLEN, J. ARTHUR, R. S. BENDER, R. ELY, H. HAUSMAN, AND E. REILLEY, *University of Pittsburgh.*—In the precision scattering project for medium energies, electromagnets have been constructed to define the energy of a beam of charged particles from the University of Pittsburgh cyclotron and to analyze the energy of charged particles emerging from the target. The magnets are designed for H_ρ values up to 10^8 gauss-cm. After fabrication according to preliminary design, the pole pieces are trimmed empirically using polonium alpha-particles. With a source width and detector slit width of $\frac{1}{16}$ inch, at a solid angle of 0.001 steradian, the resolution in momentum has a width at half-maximum less than 1 part

in 500. For 8-Mev protons, the dispersion figure is 13 kev per mm.

* Assisted by the joint program of the ONR and AEC.

M11. Magnet Current Control Unit.* E. M. REILLEY, III, AND R. S. BENDER, *University of Pittsburgh.*—An electronic control unit capable of regulating the current from a large generator has been devised and used with magnets of size from 1 ton to 100 tons. An amplidyne generator is used to drive the large generator. The circuit is essentially a dc potentiometer whose dc error signal is chopped by a vibrating reed switch, the resultant ac voltage being amplified by a large factor and demodulated. Negative feedback is provided both from the amplidyne output and the main generator output in order to stabilize systems. Currents up to 100 amperes have been stabilized to better than one part in 100,000 for a period of one hour.

* Assisted by the joint program of the ONR and AEC.

M12. Automic Operation of a Beta-Ray Spectrometer.* W. C. KELLY AND K. J. METZGAR, *University of Pittsburgh.*—Apparatus has been developed which permits the collection of data with a magnetic lens beta-ray spectrometer without requiring the attendance of the operator. The apparatus does electronically, in a repetitive fashion, what the operator would otherwise do in adjusting the focusing current and finding the time to accumulate a given number of counts. Cyclically, the following events occur. (1) A pre-set change is produced in the current by means of a helipot driven by a synchronous motor. (2) The time is stamped on a paper tape. (3) The scalar accumulates 2000 counts from the Geiger counter on the spectrometer. (4) The final time is stamped. The magnitude of the change produced in the current is determined by the time required for the scaler to accumulate 2000 counts at a standard pulse rate furnished by a blocking oscillator. An electronic switch then disconnects the blocking oscillator from the scaler and connects the Geiger counter. Results obtained with the apparatus will be described.

* Assisted by the joint program of the ONR and AEC.

M13. A 300-Volt and an rf Power Supply.* H. J. HAUSMAN, R. S. BENDER, AND E. M. REILLEY, *University of Pittsburgh.*—A general purpose rf power supply has been developed for use with photo-multiplier tubes, proportional counters, etc., capable of an adjustable output voltage of from 500 to 3000 volts, and having a short time regulation of 0.01 percent and a long time regulation of 0.03 percent at a maximum current of 1 ma. A general purpose laboratory 300-volt power supply has also been designed having a maximum output current of 250 ma regulated to 0.03 percent, hum level of 1 mv. Detailed performance figures will be given.

* Assisted by the joint program of the ONR and AEC.

SATURDAY AFTERNOON AT 2:15

Mellon Institute Auditorium

(G. E. UHLENBECK presiding)

Conclusion of the Symposium (DCP) on Statistical-Mechanical Aspects of Chemical Physics

N1. The Statistical-Mechanical Theory of Spherical and Plane Interfaces. F. P. BUFF, *University of Rochester.* (30 min.)

N2. Relations between Plasticity, Electrical Resistances, and Rates of Magnetization. HENRY EYRING AND PETER GIBBS, *University of Utah.* (30 min.)

N3. The Stability of Chemical Reactions in Extended Media. BRUCE HICKS, *Aberdeen Ballistics Research Laboratory.* (30 min.)

N4. Radial Distribution Functions in Solutions Composed of Large Ions. JACOB MAZUR, *University of Chicago,* and J. G. KIRKWOOD, *California Institute of Technology.* (30 min.)

SATURDAY AFTERNOON AT 2:15

Cathedral of Learning, Room 324

(R. SMOLUCHOWSKI presiding)

Invited Paper

P1. The New Cyclotron of the Carnegie Institute of Technology. E. C. CREUTZ, *Carnegie Institute of Technology.* (25 min.)

Magnetism; Non-Metallic Crystals

P2. Observation of Magnetic Domains by the Kerr Effect. H. J. WILLIAMS, F. G. FOSTER, AND E. A. WOOD, *Bell Telephone Laboratories.*—Magnetic domains have been observed by means of the Kerr magneto-optic effect. Plane polarized light incident normal to a surface with normal magnetization is rotated upon reflection, the sense of rotation depending upon the polarity of the surface. By using a Bausch and Lomb Research Metallographic microscope equipped with a Foster prism and a polarized light compensator[1] magnetic domains have been observed on surfaces of cobalt cutting the *C* axis

which is the direction of easy magnetization.[2] The change in domain pattern as a function of the angle between the surface and the *C* axis has been observed on a cylindrical surface of a single crystal.

[1] Turner, Benford, and McLean, Econ. Geol. **40**, No. 1 (1945).
[2] Williams, Foster, and Wood (to be published).

P3. The Magnetic Susceptibility of Chromium. T. R. McGuire and Charles J. Kriessman, Jr., *U. S. Naval Ordnance Laboratory.*—The magnetic susceptibility of metallic chromium[1] has been determined as a function of temperature from 20°C to 1460°C. A body-force method of measurement was used in conjunction with a balance previously described.[2] Several sets of measurements have been made on chromium samples which were subjected to various heat treatments. For a specimen which was annealed at 1400°C in vacuum, the magnetic susceptibility was found to increase regularly with temperature from 3.70×10^{-6} emu per gram at 20°C to 4.25×10^{-6} emu per gram at 1460°C. Field dependence measurements showed a decrease in susceptibility with increasing *H* which is attributed to a slight ferromagnetic impurity. The measurements will be discussed with regard to the probability of metallic chromium being antiferromagnetic.

[1] The chromium used, having high purity, was kindly furnished by L. D. Armstrong who had previously used it for specific heat measurements. See L. D. Armstrong and H. Grayson-Smith, Can. J. Research, **A28**, 51 (1950).
[2] T. R. McGuire and C. T. Lane, Rev. Sci. Instr. **20**, 489 (1949).

P4. On the Quantum Theory of Antiferromagnetism.* Ralph J. Harrison,† *M.I.T.*—In neutron diffraction experiments on antiferromagnetic crystals, attention must be paid to quantum effects when interpreting results for short and long range magnetic order. The uncertainty principle for angular momentum shows the Ising model is inadequate to describe magnetic ordering of an antiferromagnet. For antiferromagnetism, concepts drawn from molecular theory are more useful. Thus, the "bond order"[1] is a measure of the short range correlation in direction of spin magnetic moment. For the linear antiferromagnet we have obtained an expansion of the lowest spin eigenfunction in terms of an infinite set of valence bond spin functions, grouped according to "degree of excitation."[2] This eigenstate description supplements previous treatments of this linear case by Bethe,[3] Slater,[4] and Hulthén.[5]

* This work has been supported in part by the Signal Corps, the Air Materiel Command, and ONR.
† Now at Battelle Memorial Institute.
[1] W. G. Penney, Proc. Roy. Soc. (London) **A158**, 306 (1937).
[2] L. Pauling and G. W. Wheland, J. Chem. Phys. **1**, 362 (1933).
[3] H. Bethe, Physik **71**, 205 (1931).
[4] J. C. Slater, Phys. Rev. **38**, 1109 (1931).
[5] L. Hulthén, Arkiv Mat. Astron. Fysik **26A**, No. 11 (1938).

P5. High Temperature Phases of WO_3. W. L. Kehl, R. G. Hay, and D. Wahl, *Gulf Research and Development Company.*—Tungsten trioxide (WO_3) has been examined at temperatures up to 980°C by means of differential thermal analysis and x-ray diffraction. The differential thermal analysis curve exhibited strong reversible endothermic peaks centered at 750°C and 915°C. Debye-Scherrer x-ray diffraction patterns were obtained at room temperature and in the temperature interval from 600°C to 980°C. A new tetragonal form appeared in the pattern taken at 740°C. No further structural changes were observed up to 980°C which might explain the peak in the differential thermal analysis curve at 915°C.

P6. Low Temperature Luminescence of Inorganic Solids. Clifford C. Klick, *Naval Research Laboratory.*—The emission spectra of a representative group of inorganic solid phosphors have been measured at temperatures down to 4°K. Only phosphors having "edge" emission show a tendency to become a line spectrum at low temperatures; the ordinary impurity activated materials show little or no change in emission below 100°K. Emission of single crystal phosphors does not differ from that of the same material after grinding; nor does an increase in concentration of impurity from one part per million to one part per thousand have an appreciable effect. It is therefore improbable that the breadth of emission is due to the interaction of the luminescent center with other impurities or lattice defects. Possible explanations of the broad band low temperature emission are the existence of a zero-point vibrational energy of a non-photo-conducting luminescent center in its excited state; and, in the case of photo-conducting phosphors, the distortion of exciton and conduction levels near the luminescent center.

P7. Optical Properties of Counting Diamonds.* R. K. Willardson and G. C. Danielson, *Iowa State College.*—The relation of ultraviolet transmission, infrared absorption, luminescence, and birefringence to the gamma-counting properties of thirty diamonds will be described. The classification of diamonds into two types (I and II) on the basis of their ultraviolet transmission is not useful in selecting diamonds which will count gamma-rays, because most counting diamonds are in an intermediate class or are a mixture of the two types. An infrared absorption peak at 21 microns has been observed. The absence of strong infrared absorption peaks in the 5, 8, and 21 micron regions is a necessary but not a sufficient condition for gamma-counting diamonds. In specifying the initial counting condition of a diamond, it is not always sufficient to specify absence of polarization due to trapped carriers, because many diamonds appear to retain a positive charge for long periods of time. This positive charge induces a negative charge on the electrodes and thus influences the pulse height. This condition cannot always be eliminated by removal or reversal of the electric field. The value for the product of the mobility and mean lifetime is usually much larger for crystals of greater thickness.

* This work was performed in the Ames Laboratory of the AEC.

P8. Dielectric Loss and Ionic Conductivity in Alkali Halides. B. W. Henvis, J. W. Davisson, and E. Burstein, *Naval Research Laboratory.*—The dielectric loss of a series of alkali halides with and without added impurities has been measured as a function of temperature and frequency. The anomalous loss peaks which Breckenridge[1] reported in the dielectric loss curves of alkali and heavy metal halides were not observed in these measurements although special effort was made to find them. Any irregularities in the loss curves which were noted could be traced either to improper electroding or to erratic temperature control. One of the important results of the investigation is the development of an ac method for determining the ionic conductivity of alkali and heavy metal halides by dielectric loss measurements. This method has the advantage of eliminating polarization effects which complicate dc measurements. Results obtained with it are in good agreement with those obtained by dc pulse methods.[2]

[1] R. G. Breckenridge, J. Chem. Phys. **16**, 959 (1948).
[2] H. W. Etzel and R. J. Maurer, J. Chem. Phys. **18**, 1003 (1950).

P9. Piezoelectric Coefficients of Polycrystalline Barium Titanate in the Tetragonal and Orthorhombic States. G. N. Cotton and Hans Jaffe, *The Brush Development Company.*—The piezoelectric coefficient g_{31}, giving voltage output per applied stress, was measured on polycrystalline barium titanate over a temperature interval including the second transition point near 15°C. A sample polarized above this point shows only minor variation of g_{31} in this range. A sample polarized and measured below the transition point shows a coefficient about 40 percent higher than the sample polarized at room temperature. Upon warming through the transition point, g_{31} drops sharply to its room temperature value and maintains this lower value on renewed cooling. An elementary theory of the piezoelectric effect in polarized polycrystalline barium titanate states that g_{31} should be proportional to

retained polarization. Single crystal studies[1,2] have shown that barium titanate passes from tetragonal to orthorhombic quasi-cubic symmetry at the second transition point, the amount of spontaneous polarization remaining nearly constant. Higher values of polarization and g_{31} in the polycrystalline material below the transition point can be explained at least in part by the presence of twelve directions of spontaneous polarization in the orthorhombic state, compared with only six such directions in the tetragonal state.

[1] P. W. Forsbergh, Jr., Phys. Rev. **76**, 1187 (1949).
[2] H. F. Kay and P. Vousden, Phil. Mag. **40**, 1040 (1949).

P10. The Infrared Spectra of Crystalline Tetranitromethane.* P. H. LINDENMEYER AND P. M. HARRIS.—X-ray investigations have indicated the existence of two crystalline forms of $C(NO_2)_4$. Just below its freezing point the crystal is body-centered cubic, whereas powder photographs at the temperature of liquid air could not be indexed in either the cubic or tetragonal systems. Cooling curve investigations show that the transition between these two crystalline forms occur at −98.8°C and the transition is a "lambda-type" typical of order-disorder transitions. The infrared spectra of tetranitromethane were obtained at 25°C (vapor), 18°C (liquid), −40°C (solid I), −88°C (solid I), −104°C (solid II), and −126°C (solid II). A normal coordinate analysis was carried out to the point of completely assigning the fundamental modes. The spectra of the vapor can best be interpreted by a molecule with S_4 symmetry. The reported Raman spectra,[1] however, strongly indicate D_{2d} symmetry. Satisfactory agreement between these and the x-ray data is obtained by assuming molecules of both symmetries exist. The appearance of frequencies attributed to torsion about the C−N bond precludes internal rotation of the nitro groups. We observed a complete lack of selection rules in both crystalline forms, as has been predicted for the spectra of disordered crystals.

* This work was supported in part by a contract between the ONR and The Ohio State University Research Foundation.
[1] Mathieu and Massignon, Compt. rend. **211**, 323 (1940).

P11. An Investigation of Plastically Deformed Crystals. D. WAHL,* *M.I.T.*—The plastic deformation by bending and the subsequent annealing of lithium fluoride single crystals have been studied. Most measurements were made on crystals bent to ½-inch radius on a special machine. With the microscope, traces (which disappeared after annealing) of the 110 slip planes were visible with spacings of 0.01 mm along the curve and 0.05 mm along the height of the crystal. Crossed polarizers made the strains "visible" with spacings along the curve of 0.01 mm. These strains disappeared slowly on annealing. An x-ray technique showed strains remaining in a minute section of a sample and the disorientations of the crystallites. Crystallographically, these small blocks varied by about 45 minutes of arc from a mean direction. On annealing, the deformed crystal underwent recrystallization and grain growth at temperatures above 600°C. The new grains had the same deviations from the mean but grew to 0.06 mm along the curve of the crystal. This indicates a mosaic block structure with strain in the deformed crystal that recrystallizes on annealing to a larger block structure without strain. The 45-minute deviation is relatable to the rotation of slip lamellae under tension. The work was done in the laboratory of Professor D. C. Stockbarger.

* Formerly, Harshaw Research Fellow; present address: Gulf Research and Development Company, Pittsburgh, Pennsylvania.

Post-deadline Papers, if any

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